

Clinical Predictors of Adherence to Low Tidal Volume Ventilation Practice: Is it Different on Weekend and Night Shifts?

Rashid N. Nadeem¹, Ashraf M. Elhoufi¹, Mohamed A. Soliman¹, Islam Bon¹, Zaineb A. Obaida¹, Mayada M. Hussien¹, Lamiaa Salama¹, Ahmed N. Elsoussi¹, Sahish Kamat¹, Rami M. Satti¹, Naheed Elahi¹, Raed H. Abuhijleh¹, Moatz G. ElZeiny¹, Hitham Fargaly¹, Mohamed M. Ibrahim¹

1. Intensive Care Medicine, Dubai Hospital, Dubai, ARE

✉ **Corresponding author:** Rashid N. Nadeem, rnadeem@dha.gov.ae

Disclosures can be found in Additional Information at the end of the article

Abstract

Background: Low tidal volume ventilation (LTVV) strategy improves outcomes; however, despite recommended by guidelines, adherence to this practice is not high.

Methods: Tidal volume for mechanically ventilated patients were recorded for each 12-hour shift, day and night shifts for consecutive 101 patients. Adherence was determined by comparing these tidal volumes to standard low tidal volumes of 6 ml/kg of ideal body weight. Adherence rates were calculated and adherence rates of daytime shifts were compared to those of night time shifts. Adherence rates for weekday shifts were compared with those of weekend shifts. Clinical variables were recorded to analyze predictors of adherence pattern.

Results: The sample size was 101 patients with 870 patient-ventilator days with 1734 patient ventilator shifts. Shift adherence was only 47.5%. There was no significant difference between day and night shifts or weekday and weekend shifts. Stepwise multiple regression analysis shows that age, gender, body mass index (BMI), and partial pressure of carbon dioxide (PCO₂) have significant correlation with adherence to LTVV practice.

Conclusion: The study found that adherence to lung protective low tidal volume mechanical ventilation practice is low. Practice adherence is not different over weekend or night shifts. Age, gender, BMI, and PCO₂ have significant correlation with adherence to LTVV practice.

Categories: Cardiac/Thoracic/Vascular Surgery, Internal Medicine, Pulmonology

Keywords: low tidal volume ventilation, hypoxemia, lung protective ventilation, acute lung injury, adherence, hypercapnia, outcomes, low tidal volume ventilation, shifts

Introduction

Respiratory failure is a syndrome rather than a single disease process. The overall frequency of respiratory failure is not well known [1], for which patients require mechanical ventilation. Positive pressure ventilation is non physiologic and may cause adverse effects including pulmonary barotrauma and its associated negative consequences on the lung. It may lead to alveolar rupture resulting in the release of air into extra-alveolar spaces [2]. The incidence of barotrauma during mechanical ventilation varies with the underlying indication for mechanical ventilation but ranges from 0%-50% [3]. Low tidal volume ventilation (LTVV) is referred to as

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lung protective ventilation that aims to avoid alveolar over-distension, which is one of the principal mechanisms of ventilator-induced lung injury (VILI). VILI may lead to further pulmonary damage by causing increasing alveolar permeability, interstitial and alveolar edema, alveolar hemorrhage, hyaline membranes, loss of functional surfactant, and alveolar collapse [4-7]. LTVV is recommended to be 4 mL/kg to 8 mL/kg of predicted ideal body weight provided that inspiratory plateau airway pressure remains ≤ 30 cm H₂O [8]. Collectively, evidence suggests that the early application of and adherence to LTVV decreases mortality as well as other clinically important outcomes in patients with acute respiratory distress syndrome (ARDS) [9]. Although proved beneficial, LTVV has negative effects including increased need for sedation, auto-PEEP (positive end expiratory pressure) from resultant high frequency of respiratory rate to achieve target minute ventilation, which may cause hypercapnic respiratory acidosis [10-11]. There are conditions in which this high partial pressure of carbon dioxide (PCO₂) has deleterious consequences such as acute cerebral disease, coronary artery disease, heart failure, cardiac arrhythmias, pulmonary hypertension with right ventricular dysfunction plus hypovolemia; so these conditions are considered to be relative contra-indications of LTVV strategy [12-13].

In two meta-analyses including 15 and seven randomized trials, respectively, LTVV strategy in non-ARDS ventilated medical and surgical patients was associated with lower mortality, less incidence of ventilator associated pneumonia (VAP) plus ventilator associated lung injury (VALI) in addition to less progression to ARDS [14-15]. Despite robust evidence demonstrating multiple benefits of LTVV in ARDS, the acceptance of this practice is disturbingly low. Major barriers to utilization of LTVV are the inability to recognize and tailor tidal volume to ideal body weight (IBW) (a function of height and gender) and use of non-volume control modes of ventilation. Less common barriers to the implementation of LTVV include the fear of increased sedation needs, lack of acceptance of permissive hypercapnia, management of refractory hypoxemia, and multidisciplinary team dynamics [16-17]. Finally, the most important barrier is poor recognition of ARDS by clinicians [18]. We conducted a retrospective medical records review study to determine adherence to this standard practice of LTVV at our community hospital and to investigate if there is a different pattern in adherence practice over weekend days in comparison to weekdays. We also aimed to determine if there are any clinical factors that are correlated with adherence.

Materials And Methods

We performed a retrospective medical records review study at a single medical center, Dubai Hospital, Dubai. All medical records of mechanically ventilated patients who were admitted to the intensive care unit of the Dubai Hospital from August 2017 to July 2018 were reviewed if they met the following inclusion criteria.

Inclusion criteria

All patients admitted to the ICU who received mechanical ventilation for more than 24 hours.

Exclusion criteria

The exclusion criteria were contraindication to LTVV (intracranial pathology, intracranial hemorrhage (ICH), cerebrovascular accident (CVA), known high previous PCO₂, acute exacerbation of chronic obstructive pulmonary disease (COPD) with high PCO₂, cardiogenic shock).

Definitions

All patients' ventilator settings (tidal volume (TV), positive end expiratory pressure (PEEP), and plateau pressure) were recorded daily from the morning shift (9AM-9PM) and at night (9PM-

9AM).

Ideal body weight was calculated for each patient using the J. Devine Formula (1974) [19].

Male patients: $IBW (kg) = 50 + 2.3 (\text{height [inches]} - 60)$.

Female patients: $IBW (kg) = 45.5 + 2.3 (\text{height [inches]} - 60)$.

Male patients: $IBW (kg) = 50 + 2.3 (\text{height [cm]}/2.54 - 60)$.

Female patients: $IBW (kg) = 45.5 + 2.3 (\text{height [cm]}/2.54 - 60)$.

Tidal volume was calculated for all patients as 6 ml/kg of IBW.

Patient ventilator days were calculated by multiplying patient number by days of ICU stay with mechanical ventilation. Adherence was determined for each shift (day and night) by comparing ideal tidal volume and actual tidal volume.

Confounding variables affecting target measures

We also recorded the following variables that may affect adherence to this practice: primary diagnosis to classify ARDS versus non-ARDS diagnosis, tracheostomy versus endotracheal tube, X-ray chest abnormality (presence or absence of infiltrates), arterial blood gas PH, PCO₂, partial pressure of oxygen (PaO₂) and fraction of inspired oxygen (FiO₂). Demographics (age, gender, BMI) were also recorded. We also recorded acute physiology and chronic health evaluation (APACHE) scores at 24 hours after admission to the ICU and the final outcome of the patient at discharge from the ICU (alive or dead).

Statistical analysis

Adherence rate was determined for day and night shifts as well as weekend and weekday shifts. These rates were compared. There was no significant difference in variables compared between adherent and non-adherent subjects. We conducted stepwise multiple regression analysis using the Statistical Package for the Social Sciences (SPSS) software Version 25.0 (IBM Corp. Armonk, NY).

Results

Tidal volume for mechanically ventilated patients were recorded for each 12-hour shift; day and night for consecutive 101 patients. Adherence was determined by comparing these TVs to standard low TVs of 6 ml/kg of ideal body weight and adherence rates were calculated. Day shift tidal volume adherence was 459/870 (52.8%) versus night shift adherence 452/864 (52.3%), $p=0.44$. Weekday adherence was 646/1263 (51.1%) versus weekends 265/471 (56.3%) $p=0.05$. Sample characteristics included age (59 +/- 20) years, gender M/F (61/40), BMI (27.1 +/- 8.1) kg/m², APACHE II score (24.6 +/- 8.3), PEEP (7.12 +/- 2.3), FIO₂ (62.9% +/- 21.4%), mortality (died 47/alive 48), endotracheal tube (ETT) versus tracheostomy (trach) (87/5), abnormal/normal chest X-ray (64/31), PH (7.27 +/- .14), PCO₂ (43.07 +/- 18.8) torr and PO₂ (134.9 +/- 106) torr. Stepwise multiple regression analysis showed that age, gender, BMI, and PCO₂ have significant correlation with adherence to LTVV practice (Table 1). Younger patients, male patients, patients with less BMI and less PCO₂ were more likely to have higher adherence rates.

Variable	Mean	SD	N	Correlation	P value
Adherence %	51.8		101	1	
APACHE score	24.69	8.31	101	-0.022	0.413
Age (years)	59.03	20.01	101	-0.273	0.003
Gender M/F	61/40		101	-0.475	0.001
BMI (Kg/m ²)	27.18	8.10	98	-0.198	0.025
PEEP (mm of water)	7.12	2.34	99	0.127	0.105
Plateau pressure (cm of water)	24.80	5.37	97	0.09	0.189
FiO ₂ (mm of Hg)	62.91	21.46	98	0.109	0.142
Dead/alive (N)	47/48		95	0.136	0.094
Trach/ETT (N)	5/87		92	-0.081	0.22
CXR infiltrate (present/Absent)	31/64		95	-0.012	0.453
pH	7.26	0.14	97	-0.055	0.297
PO ₂	134.94	106.13	97	0.117	0.127
PCO ₂	43.07	18.85	97	-0.228	0.013

TABLE 1: Stepwise multiple regression analysis (adherence against variables).

APACHE - acute physiology and chronic health evaluation, BMI - body mass index, PEEP - positive end expiratory pressure, FiO₂ - fraction of inspired oxygen, Trach/ETT - tracheostomy/endotracheal tube, CXR - chest x-ray, PO₂ - partial pressure of oxygen, PCO₂ - partial pressure of carbon dioxide

Discussion

Our study reveals that adherence to lung protective mechanical ventilation by employing low tidal volume ventilation is very poor—only about 50%—and there is no difference over weekends and night shifts. Studies showed low tidal volume ventilation strategy decreased mortality and increased the number of days without ventilator use in patients with acute lung injury and acute respiratory distress syndrome (ARDS) [20]. LTVV often requires higher level of positive end expiratory pressure (PEEP), and high levels of PEEP may improve survival in ARDS patients [21]. The practice benefit expands to non-ARDS patients as it provides similar benefit. Data regarding its generalized application in non-ARDS patients is not as significant as ARDS. On the contrary, use of LTVV intraoperatively with minimal PEEP is associated with an increased risk of 30-day mortality [22]. A more recent study showed that in patients without ARDS, low tidal volume strategy did not result in a greater number of ventilator-free days than an intermediate tidal volume strategy [23]. Many hospitals have standard protocols to ensure LTVV. Protocol directed interventions effectively decreased large tidal volumes and it was associated with a decreased frequency of new acute lung injury [24]. Protocols require an interdisciplinary approach and high number of healthcare staff, which is uncommon outside large centers, especially outside USA. Inadequate staffing (physicians and respiratory

therapists) often plays a major role in adherence to standard protocols. Lower adherence in general in our study may be reflective of this factor.

Regarding patient-specific factors, we performed regression analysis, which showed that the APACHE score is not a predictor of adherence (coefficient -0.022, P=0.410). There was no significant difference for adherence for patients with endotracheal ventilation versus ventilated via tracheostomy. Mortality was also similar for both groups. Finding of x-ray lung infiltrate was not different between non-adherent and adherent groups. The only significant factors were age, gender, and high PCO₂ levels on arterial blood gas, which is understandable, as patients with non-ARDS pathology who have high PCO₂ may have lower adherence to LTVV prescription to maintain adequate ventilation. We believe these observations may not be significant as the sample size of our study was not large enough to conclusively disassociate these factors with adherence.

Our detailed shift to shift analysis showed that patients on non-adherent shifts have lower PEEP value, higher plateau pressure and higher peak airway pressure, which suggest that if these patients have LTVV, they may have higher PEEP, lower plateau pressure and peak pressure. It only emphasizes the fact that LTVV has beneficial mechanical effects on the lung.

We identified the following weaknesses of our study. It was a single center study with a relatively small sample size, so the results are not generalizable. It does reflect the true real life practice pattern though and highlights multiple areas for us to improve outcome. Retrospective chart review study provides only weak level of evidence, but it does identify that poor adherence is a significant issue. Data on adherence to such practices are not common in this part of the developing world. With the recent incorporation of electronic medical records, institutions are becoming better equipped to monitor and identify factors affecting practice patterns, which will improve the process of quality measurement, which will translate into improved clinical outcomes. We plan to implement protocols and study these quality measures in prospective patterns, which will help us determine predictors of good quality care and improved clinical outcomes.

Conclusions

Adherence to low tidal volume mechanical ventilation practice appears to be about 50% only and it is not different over weekends or night shifts. Age, gender, BMI, and PCO₂ have significant correlation with adherence to LTVV practice. Studies are needed, especially in developing countries, to explore and improve practice of low tidal volume mechanical ventilation.

Additional Information

Disclosures

Human subjects: Consent was obtained by all participants in this study. DSREC DHA issued approval not applicable. The study was formally submitted and approved by DSREC DHA, Dubai, UAE. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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